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A 180° A GRAND TRANSFERT

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BACKWARD SCATTERING OF POSITRONS AND ELECTRONS ON PROTONS

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BACKWARD SCATTERING OF POSITRONS AND ELECTRONS ON PROTONS.

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Most electron-proton elastic scattering experiments agree perfectly with the one-photon exchange model. One can however exchange two photons in this process, for instance the 1^+ state; such diagram will introduce in the Rosenbluth formulae an interference term, the sign of which is opposite for electrons and positrons. This contribution can be observed either in the proton polarization, or in the linearity of the cross-section versus $\tan^2 \theta/2$, or in the ratio R of positron-proton to electron-proton elastic scattering. Polarization experiments⁽¹⁾ are compatible with no two photon exchange effect; also no evident deviation has been found in the $\tan^2 \theta/2$ dependence. On the other hand the first measurements of the ratio R at Stanford⁽²⁾ and C.E.A.⁽³⁾ seemed to indicate a dependence with the momentum transfer. The new measurements of Desy⁽⁴⁾ and Cornell⁽⁵⁾ are however compatible with $R = 1$. All these results have been obtained at a small electron scattering angle. We decided to perform a new ratio R measurement at 180° scattering where one can hope, when following Gourdin's interpretation⁽⁶⁾, to obtain the most accurate measurement of a possible two-photon exchange contribution.

Following Gourdin's model⁽⁶⁾, one can write the elastic scattering cross-section :

$$\frac{d\sigma}{d\Omega} (e^\pm p) = \sigma_{\text{Mott}} \left[A(q^2) + B(q^2) \tan^2 \theta/2 \pm C(q^2) \tan^2 \theta/2 \left(1 + \frac{\cot^2 \theta/2}{1 + \frac{q^2}{4M^2}} \right)^{1/2} \right]$$

$C(q^2)$ is the function which should characterize the two-photon exchange contribution and which is supposed to depend over q^2 . At 180° scattering the ratio R becomes simply :

$$R = \frac{B(q^2) + C(q^2)}{B(q^2) - C(q^2)} = \frac{1 + C/B}{1 - C/B}$$

By measuring R one deduces the ratio $C(q^2)/B(q^2)$ which can be used to characterize the two-photon exchange contribution. In any case C/B can be written as :

$$C(q^2)/B(q^2) = \frac{R - 1}{R + 1} G(q^2, \theta)$$

Thus the accuracy expected in $C(q^2)/B(q^2)$ or $C(q^2)$ determination is proportional to the accuracy in R determination and to the factor $G(q^2, \theta)$. For a given q^2 , $G(q^2, \theta)$ is a decreasing function of θ ; it is minimum and equal to one for $\theta = 180^\circ$. One sees that we reach the highest accuracy at $\theta = 180^\circ$. We did two measurements at $q^2 = 8$ and $q^2 = 32$ with $\theta = 180^\circ$; the backward scattered electron has been observed in coincidence with the forward recoil proton in order to decrease the background and to reject ^{effects} as pion contribution.

EXPERIMENTAL SET UP.

The general set up is shown in fig. 2. The momentum analysed electron beam is bent by two magnets M1 and M2 in order to enter the electron spectrometer M3 through a specially designed hole. The M3 magnetic field is adjusted to observe the backward elastically scattered electrons. The M1 and M2 magnetic fields are set to allow the beam to enter horizontally the liquid hydrogen target after passing the electron spectrometer. The thin stainless steel walls target was 32 cm in length at $q^2 = 32$ and 16 cm at $q^2 = 8$. After passing a thin foil ionization chamber, both incident beam and recoil protons enter the double focusing proton spectrometer M4. Protons are bent down towards a system of counters; in electron proton scattering the electron beam is deviated upwards

and comes out M4 through a hole drilled in the iron magnet; in positron-proton scattering the positron beam strikes the inner side of the M4 vacuum chamber, giving rise to a high background counting rate in proton counters. The magnetic field in both electron and proton spectrometer is measured with a Hall probe.

The beam centering could be done very easily and accurately at any time, owing to a system of seven sets of screen-camera-sniffers put all along the beam. The ionization chamber, used to monitor the beam and frequently calibrated against a Faraday cup, was stable to better than 0.5 %. By putting the target very close to the electron spectrometer we did reach a large solid angle, 0.10 st. Magnetic screens were disposed between the spectrometer and the target to decrease the fringing field along the recoil proton path to a negligible value. Scattered leptons were detected by two $38 \times 35 \text{ cm}^3$ scintillation counters presenting a $\Delta P/P = 10 \%$. The proton detection system consisted of a 9 channel-ladder counter sandwiched between two scintillation counters. The 9 channels of the ladder counter define a total $\Delta P/P$ of 4.5 %. The elastic scattering peak is recorded on the proton ladder counter after coincidence with electron and proton counters. Also recorded were the random events in which the lepton signal has been delayed. With $5 \cdot 10^9$ electrons/sec the random events were practically inexistant; with 10^9 positrons/sec the random events amounted to 15 %, due to the high background produced by the positron beam hitting the spectrometer. The random positron yield has been measured by comparing it to the random electron yield obtained by inverting the magnetic field in the proton spectrometer and using electrons. In both cases the random events were found equal. To decrease this background we inserted a 5 cm thick lead plate in front of the proton counters, thus losing 30 % in real elastic events; the lead was left in the electron experiment to keep the whole system identical for both positrons and electrons. Empty target yields were found negligible.

A total of 2500 electron events and 1200 positron events were recorded on the ladder counter. The momentum spectra obtained for $q^2 = 32 \text{ F}^{-2}$ are shown in fig. 2.



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The whole apparatus was first checked by deducing the form factors from the electron yield of this experiment. Our values were found compatible with those obtained by other laboratories.

All the classical electron-proton scattering corrections have been made and radiative corrections have been taken care of, especially since they are large and have different values for electrons and positrons. The accuracy in radiative corrections is now of order 1 %; more elaborate calculations are being done by Reinhart⁽⁷⁾.

Table I gives the preliminary results.

In electron measurements the error is mainly statistical. In positron measurements the error is increased because of the background subtraction. Fig. 4 shows the q^2 dependence of $C(q^2)/B(q^2)$ measured experimentally in various laboratories. Two points have been done previously at Orsay by Tchaptoutian et al⁽⁸⁾ by observing the scattered electron only. The mean value of $C(q^2)/B(q^2)$ obtained in different laboratories is compatible with zero. However our points favour a slightly positive value.

We are indebted to Professor Blanc-Lapierre for his constant support of this experiment. We would like to thank the laboratory staff for their effort in providing us with a good positron beam and an excellent apparatus. We had fruitful discussions with A. Browman and P. Bounin, it is a pleasure to thank them.

E_o MeV	q_F^{-2}	$\frac{\sigma(e^+p)}{\sigma(e^-p)}$ non corrected	$\frac{\Delta P}{P}$ proton	Ω proton	$\frac{\Delta P}{P}$ electron	Ω electron	radiative corrections	$R = \frac{\sigma(e^+p)}{\sigma(e^-p)}$ corrected	$\frac{C(q^2)}{B(q^2)}$
380	8	$1,075 \pm 0,018$	0.030	0.0050	0.10	0.10	1.047	$1,038 \pm 0,016$	$0,019 \pm 0,008$
980	32	$1,150 \pm 0,054$	0.015	0.0040	0.10	0.10	1.094	$1,058 \pm 0,050$	$0,029 \pm 0,025$

TABLE I.

FIGURE CAPTIONS

- Fig. 1 General experimental set up. Magnets are designed by M, scintillators by S, screen-sniffers by E, and the ionization chamber by IC.
- Fig. 2 Proton spectra at $q^2 = 32 \text{ F}^{-2}$.
a) Electron-proton scattering.
b) Positron-proton scattering with the background non-subtracted.
c) Positron-proton scattering after background subtraction.
- Fig. 3 $C(q^2)/B(q^2)$ versus q^2 .

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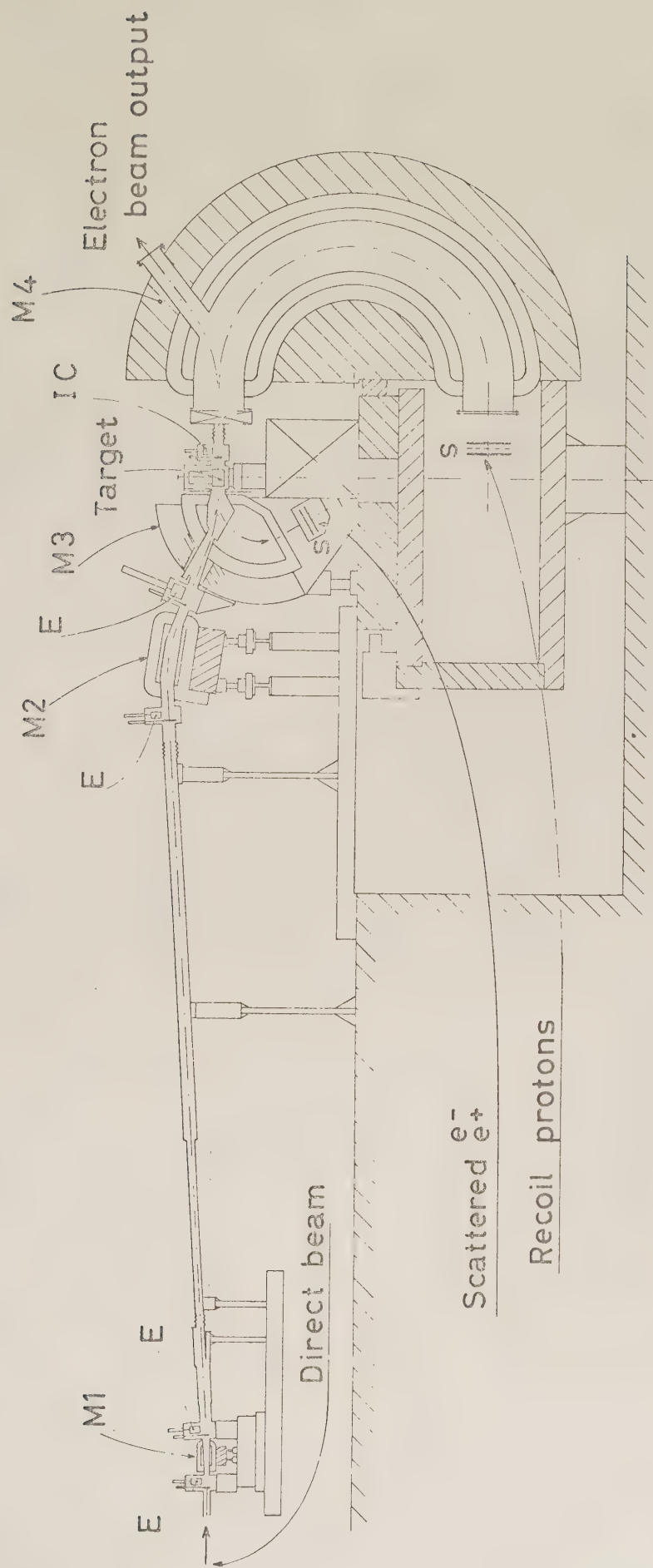


Fig. 1

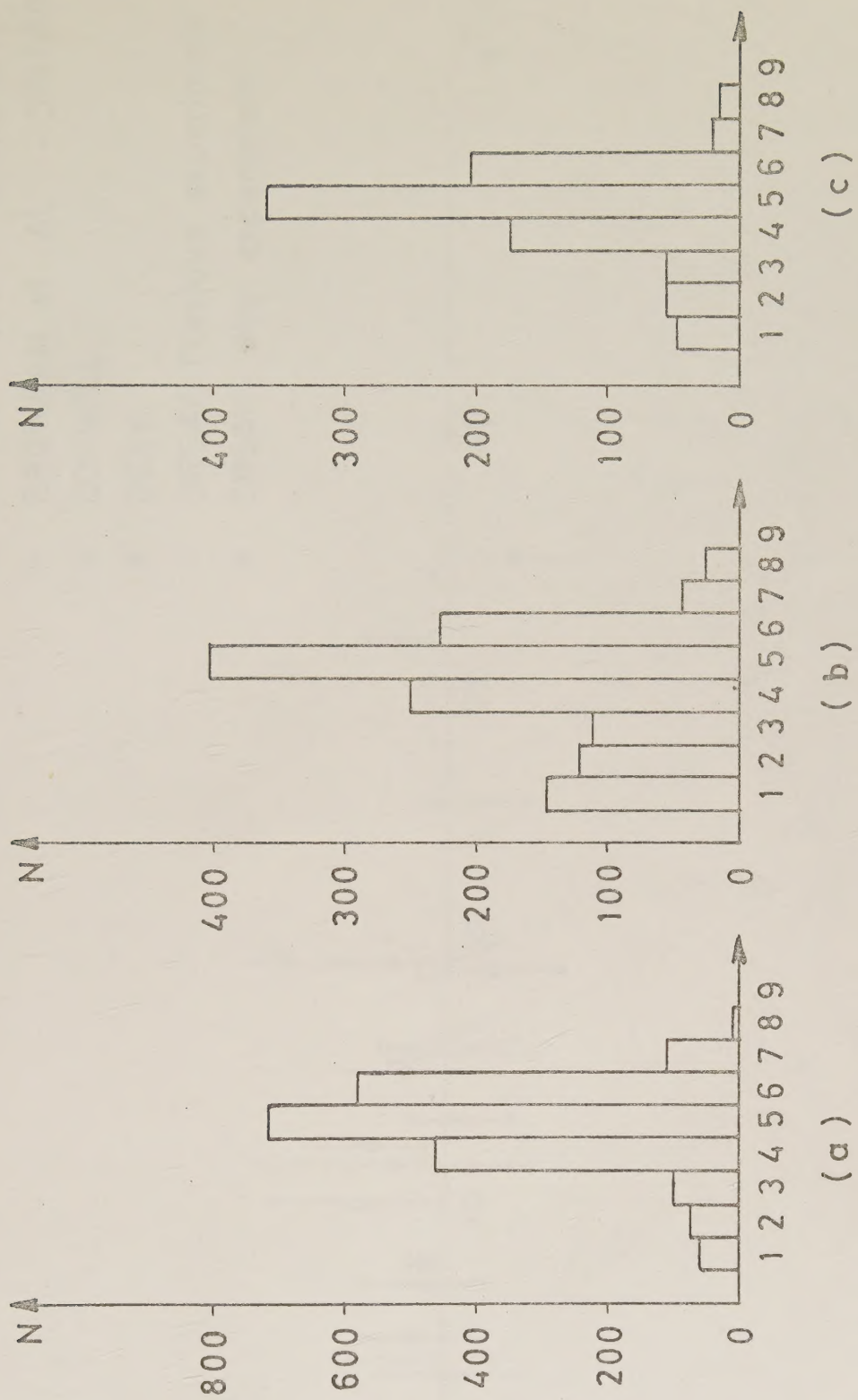


Fig. 2

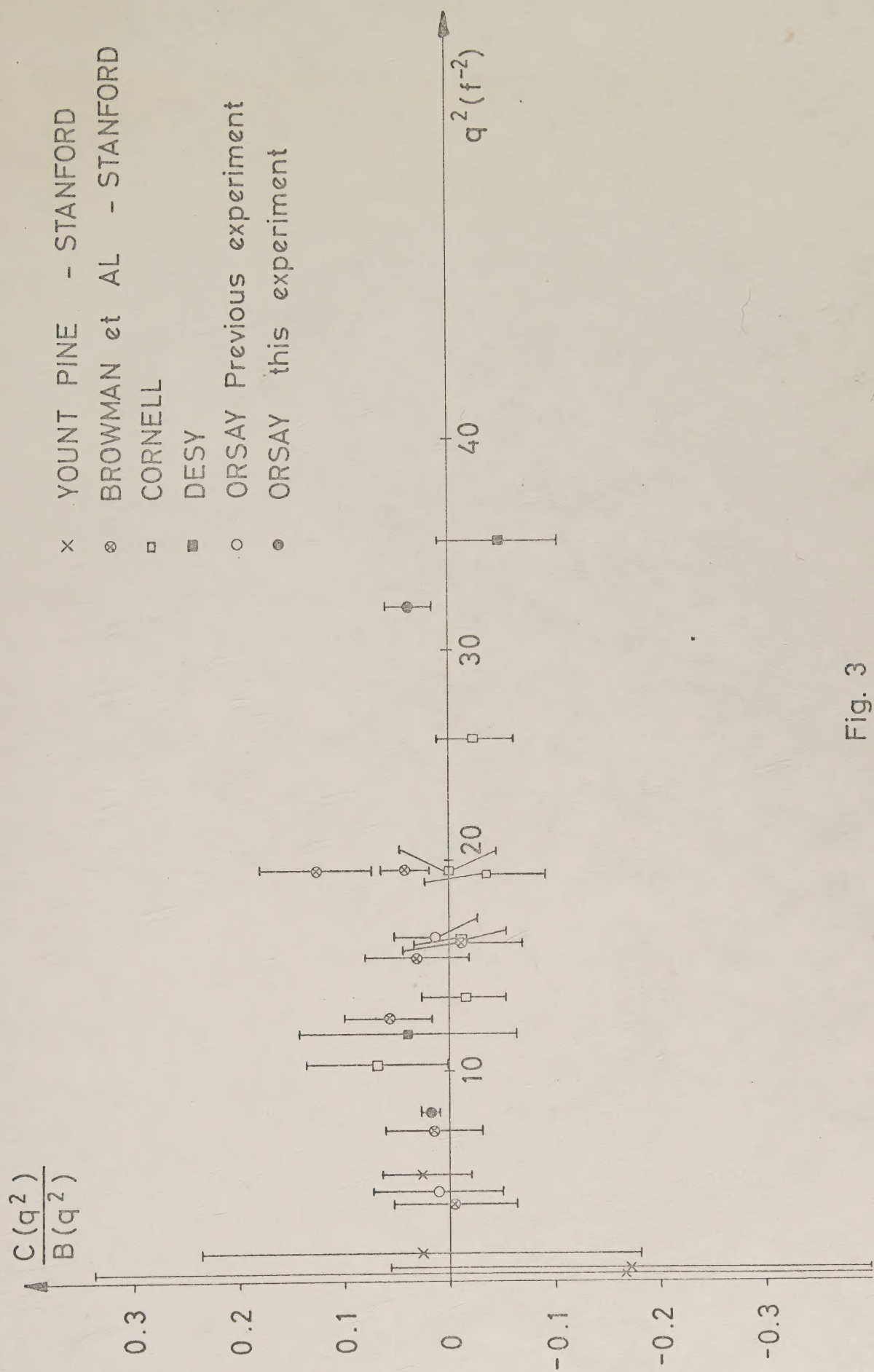


Fig. 3

